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(54) **Cable sheathing control**

(57) In a process in which a sheath is extruded onto a core 11 of great length, the extrusion rate of the extruder 15 and the feed rate of the core 11 are controlled. The thickness of the core 11 is monitored at 8 in advance of the extruder 15 and the thickness of the sheathed core member is monitored at 9. The control system 30, operating according to a predetermined algorithm, receives the monitored values of thickness together with a data input defining the required sheath thickness and generates signals to effect control of the extrusion rate and core feed rate.

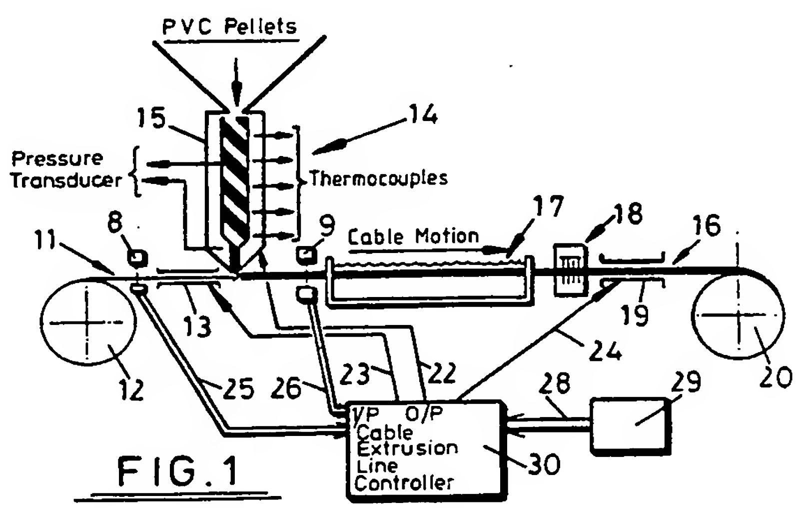

FIG.1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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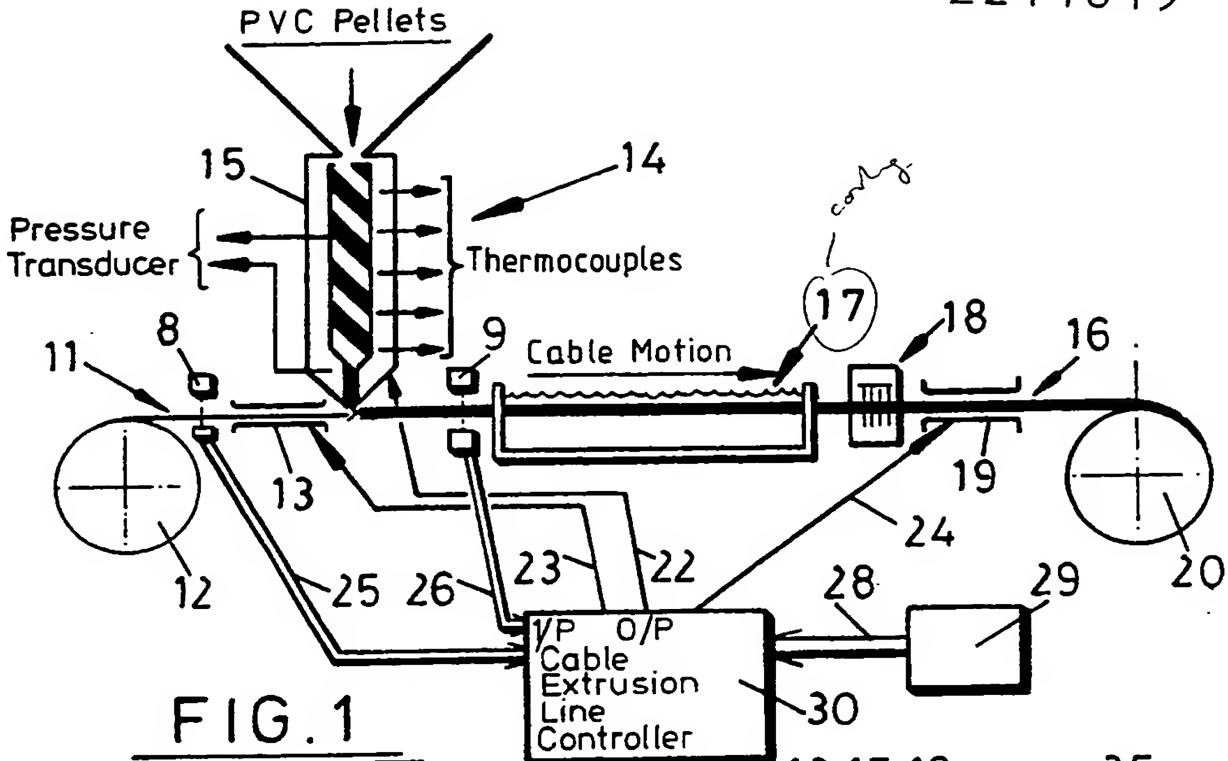

FIG. 1

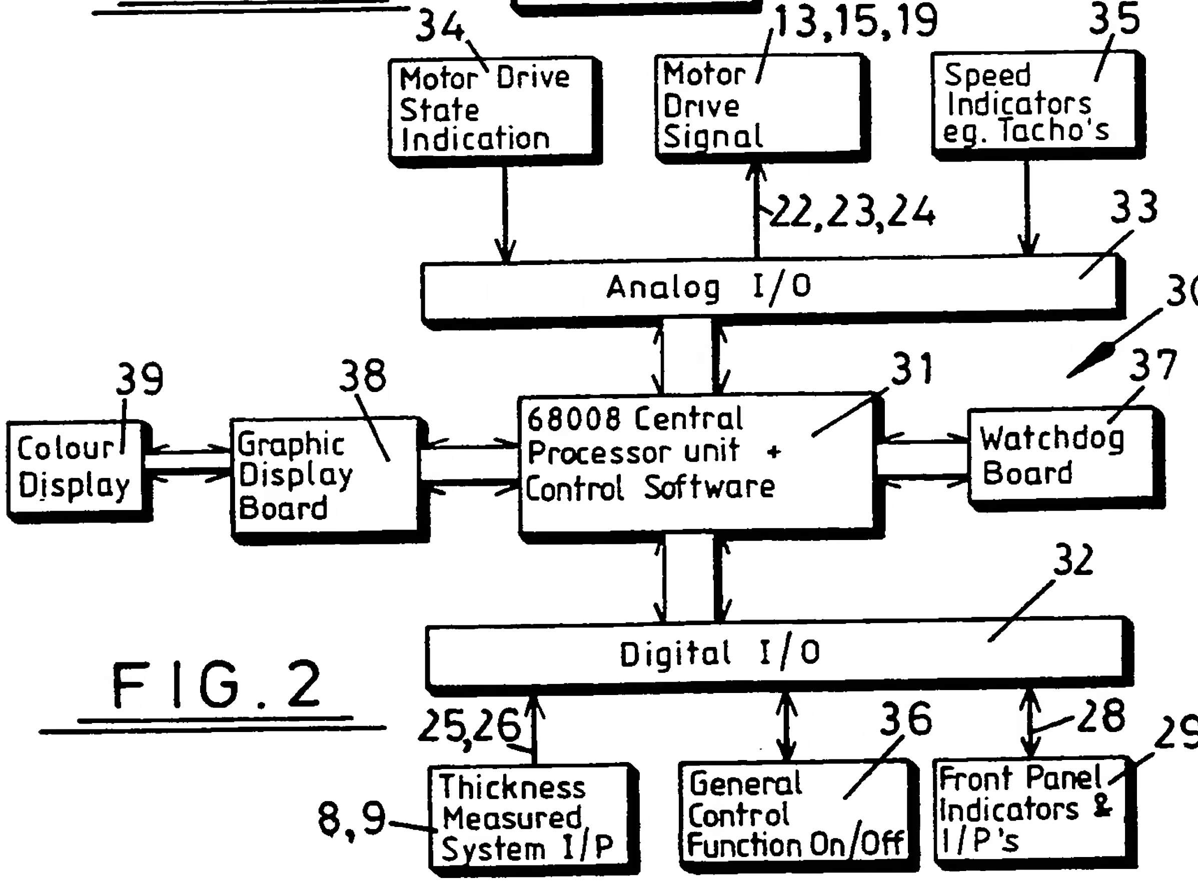

FIG. 2

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PROCESS CONTROL SYSTEM

This invention relates to a control system for controlling operation of a process in which a sheath is extruded onto a core member of very great length. The invention is particularly applicable to the manufacture of electric cable.

In the manufacture of electric cable where pvc insulating material is extruded to form a sheath around a copper conductor, conductor bundle or armoured casing around one or more conductors, the manufacturing process relies upon an experienced operator to govern the rate at which insulation material is extruded from an extruder and the rate at which the core to be sheathed is fed through the extruding station. The operator is assisted by laser micrometers upstream and downstream of the extruding station which issue measures of the core before sheathing and of the sheathed core respectively, and the operator is provided with a manufacturing specification identifying a required minimum insulation thickness. The operator controls the process by visually reading the micrometer thickness measures and adjusting the core feed speed and the extruder feed speed until he thinks the insulation thickness is correct. This arrangement has the disadvantages that the operator requires significant experience, the speed or feed controls are adjusted imprecisely and infrequently as a result of which over

the total core length there are large variations in insulation thickness, excess insulation material is used and large quantities of reject cable are produced.

It is an object of the present invention to provide a new and improved control system for controlling operation of a process in which a sheath is extruded onto a core member of very great length.

According to the present invention there is provided a control system for controlling operation of a process in which a sheath is extruded onto a core member of very great length, said system comprising first means for controlling the extrusion rate of the extruder, second means for controlling the feed rate of the core member through the extruder, third means for monitoring the thickness of the core member in advance of the extruder, fourth means for monitoring the thickness of the sheathed core member, and processor means operating according to a predetermined algorithm and having its inputs coupled to said third and fourth means and its outputs coupled to said first and second means and having a reference input arranged to receive data defining the required sheath thickness.

Preferably the processor means is arranged to average the outputs of each of the third and fourth means over a predetermined time interval and to apply said average values to the predetermined algorithm.

Preferably the predetermined algorithm takes a first form for start up of the process and a second form for subsequent operation of the process, said second form being initiated after a predetermined time interval sufficient to permit said fourth means to provide a thickness measure greater than that provided by said third means.

Conveniently said first form of algorithm provides an output to operate the second means at a predetermined value and provides an output to operate the first means at a value dependant upon the predetermined value of the second means and upon the required thickness of the sheath.

Conveniently also said second form of algorithm provides an output to operate the second means at a level determined by the error established by the processor means between the required sheath thickness and the monitored value derived from the third and fourth means whilst maintaining constant the output to operate the first means.

Preferably said second form of algorithm includes a regression routine to determine and update approximations throughout the duration of the process.

An embodiment of the present invention will now be described by way of example with reference to the accompanying drawings, in which:

Fig. 1 is a simplified diagram illustrating a process

incorporating a control system according to the present invention; and

Fig. 2 is a block diagram showing interconnections of the control system.

In Fig. 1 of the drawings manufacture of an electric cable comprises a process in which an unsheathed conductor core member 11 is pulled from a pay off reel 12 by an input caterpillar drive unit 13 in order to pass the core member 11 through a sheathing station 14 having a p.v.c. extruder 15. The pvc sheathed core member or cable 16 thereafter traverses a cooling station 17, which in this example is a water trough, a spark tester 18 for monitoring the insulation quality of the pvc sheath, and an output caterpillar drive unit 19 before being wound onto a take-up reel 20. Extruder 15 which is of the screw and barrel type is temperature controlled to ensure that the extruded material is of optimum quality. The extrusion rate of the extruder 15 is controller by its drive unit via line 22 from a control system 30 which via lines 23 and 24 controls the operation of the caterpillar drive units 13, 19, respectively so as to control the feed rate of the core member 11 through the station 14. Additionally, a measuring device in the form of a laser micrometer 8 is provided in advance of the station 14 to measure thickness of the core member 11 and to deliver that measure over line 25 to system 30, whilst a similar measuring device or micrometer 9 downstream of the station 14

measures thickness of the cable 16 and delivers that measure over line 26 to the system 30. For the purpose of infeeding data defining the required sheath thickness system 30 is connected via a reference input to a data input unit 29 via line 28.

Fig. 2 illustrates the interconnections of the control system 30 and the basic electronic hardware configuration which is based upon the standard G64 data bus and commercially available circuit boards. Thus the main component of the system 30 is a control processor unit 31 preferably a Motorola 68008 circuit board connected via a digital I/O board 32 (e.g. Syntel T101) to the two laser micrometers 8, 9, to the data input unit 29 and to various other devices 36 of peripheral interest to the present invention. Unit 31 is also connected via an analogue I/O board 33 (e.g. Syntel DAC8/ADC4) to the drive units 13, 15, 19, and to speed monitoring devices 34, 35, to ensure that the demanded speeds are correctly attained. A watchdog board 37 (e.g. Syntel BCR2/LO) supplies an accurate 24 hour clock for process time monitoring and a battery backed up memory operable in the event of mains power failure to reduce the system 30 to shut down in a controlled manner. A graphics display board 38 (e.g. Syntel CGD1) and colour monitor 39 provides visual information for the operator to follow operation of the process.

In operation of the process the control system 30 is

first initialised to a preset state and input data defining the required sheath thickness is entered via unit 29 and the process is thereafter commenced with the processor 31 operating according to a first predetermined algorithm (the start up algorithm). After a short time interval the processor continues thereafter to operate according to a second predetermined algorithm (the volume control algorithm) until such time as the process is completed by the core member 11 being exhausted. The volume control algorithm may be enhanced throughout its use by regression control.

The start up algoirthm determines at what speed the extruder 15 has to operate in order to place the required pvc thickness (Td) on a core of diameter (D) progressing through the station 14 at a fixed speed (v) which is usually set at 20 mpm to permit an operator to guide the leading end of the core through components 17, 18 and 19 and around take-up reel 20. Also, extruded volume is directly linearly proportional to extruder speed. This algorithm is derived from a consideration of the cross section of a circular sheathed cable from which it can be shown that

$$\text{Extruder speed} = \frac{\pi \cdot v\,(T_d^2 + DT_d)}{V_E}$$

where V_E is the extruder screw volumetric output provided by the extruder manufacturer or by measurement.

At start up when the extruder has reached its requird speed linear movement of the core member 11 is commenced

and this is accelerated up to the preset fixed speed (v). After a short delay to permit micrometer 9 to issue meaningful measurements the processor 31 operates using the volume control algorithm so that depending upon the average insulation thickness measured over a few seconds the line-speed is altered to a value calculated by the processor 31. If insulation thickness exceeds requirement the line is accelerated and vice versa.

The normal volume control algorithm is based upon the (valid) assumption that for a small time period of the order of a few seconds the volume of insulation extruded by the extruder 15 will be constant so that if the sheath thickness as measurerd by the difference between the readings of micrometers 8 and 9 is not as required (i.e. is not within a preset tolerance band of a preset thickness) then a new line-speed can be calculated and implemented whilst the extruder speed remains constant and the sheath thickness will thereafter be as required.

The volume control algorithm for a constant extruder output can be shown to be :

$$V_n = \frac{V_o(T^2+DT_o)}{(T^2{}_d + DT_d)}$$

where V_n = required line-speed for a new pvc thickness, T_d

V_o = present line-speed

T_o = average insulation thickness measured before line-speed change

Regression control enhances the normal volume control algorithm and is based upon the fact that for constant extruder volume the line-speed/thickness relationship follows an inverse square law, viz:

$$v \propto \frac{1}{T_d^{\,2} + DT_d}$$

and this relationship can be approximated by a series of straight lines each of different slope over any incremental line-speed range δv. Accordingly for any one of these straight lines the sheath thickness (T) will be given by

$$T = mV + c$$

where m and c are determined by least squares regression analysis from the relationships

$$m = \frac{(\Sigma V_i T_i) - (\Sigma V_i \Sigma T_i)/N}{(\Sigma V_i^{\,2}) - (\Sigma V_i)^2/N}$$

$$c = \frac{(\Sigma V_i T_i) - (\Sigma V_i^{\,2})m}{\Sigma V_i}$$

where all summations are over i = 1 to N where

N = total number of data points (V,T) measured in the range δv.

V_i = the i^{th} value of line-speed in the range δv.

T_i = i^{th} value of pvc thickness in the range δv.

$\Sigma V_i T_i$ = sum of the product v*T in the range δv.

$\Sigma V_i^{\,2}$ = sum of the product v*v in the range δv.

ΣT_i = sum of the measured T_i values in the range δv.

ΣV_i = sum of the measured v_i values in the range δv.

The regression routine allows these local line segment approximations to be determined and updated as the process progresses and accounts for changes in the characteristics of the extruder.

CLAIMS

1. A control system for controlling operation of a process in which a sheath is extruded onto a core member of very great length, said system comprising first means for controlling the extrusion rate of the extruder, second means for controlling the feed rate of the core member through the extruder, third means for monitoring the thickness of the core member in advance of the extruder, fourth means for monitoring the thickness of the sheathed core member, and processor means operating according to a predetermined algorithm and having its inputs coupled to said third and fourth means and its outputs coupled to said first and second means and having a reference input arranged to receive data defining the required sheath thickness.

2. A control system as claimed in claim 1, wherein the processor means is arranged to average the outputs of each of the third and fourth means over a predetermined time interval and to apply said average values to the predetermined algorithm.

3. A control system as claimed in either preceding claim, wherein the predetermined algorithm takes a first form for start up of the process and a second form for subsequent operation of the process, said second form being initiated after a predetermined time interval sufficient to permit said fourth means to provide a thickness measure greater than that provided by the said third means.

4. A control system as claimed in claim 3, wherein said first form of algorithm provides an output to operate the second means at a predetermined value and provides an output to operate the first means at a value dependant upon the predetermined value of the second means and upon the required thickness of the sheath.

5. A control system as claimed in claim 3 or claim 4, wherein said second form of algorithm provides an output to operate the second means at a level determined by the error established by the processor means between the required sheath thickness and the monitored value derived from the third and fourth means whilst maintaining constant the output to operate the first means.

6. A control system as claimed in claim 5, wherein said second form of algorithm includes a regression routine to determine and update approximations throughout the duration of the process.

7. A control system as claimed in claim 1 and substantially as hereinbefore described with reference to the accompanying drawing.

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